quoted as saying that at "smaller node sizes, we think switched digital star architectures are at cost parity with hybrid fiber/coax, and they offer a higher level of service quality and reliability, as well as the flexibility to offer new services in the future."[21]

B. Several Leading Manufacturers Will Provide Digital Set-Tops

The inauguration of DBS systems in 1994 also marked the beginning of commercial distribution of digital set-tops. Digital set-tops are sold as part of a package that includes the receiving antenna and amplifier, at a retail price of about $700. About 600,000 of these DBS systems are expected to have been sold by the end of 1994, according to industry estimates. The digital set-top represents about $300 of the cost of the DBS system for a unit that decodes one channel at a time. As deployment of DBS systems expands, the cost of these devices will decline.

Digital set-top technology for wireline video delivery systems also is well along the development cycle. Trial systems using various transport technologies have been operational for some time. Now that the MPEG 2 (digital video encoding and compression algorithm) standard is complete, commercial set-top manufacturers have announced plans to sell digital set-tops. Philips Consumer Electronics will supply digital set-tops for use in receiving digital content over the FLX system being deployed in Dover Township. Prototype versions of the Philips unit are currently in use, and the commercial product will be available in early 1995.

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[21] *Id.* at 7.

AT&T announced recently that it intends to develop and provide a line of digital set-tops. AT&T reportedly will ship 20,000 "digital video home terminals" to Cablevision Systems Corp., a cable TV operator, by mid-1995. AT&T will make a "more advanced" version of the digital set-top available in 1996, according to press reports.[22] Despite reported delays, General Instrument, one of the leading set-top converter manufacturers, has indicated that it remains committed to begin shipping its DigiCable digital set-top in July 1995.[23]

1) Transport Architecture Affects the Complexity and Cost of Digital Set-Tops

A digital set-top consists of two subsystems. The first is the decoding and display subsystem. It contains those service-specific elements that decode the digital signal to analog and create the analog display. A decoder, RAM and a microprocessor are the major components of this subsystem. The second subsystem is the network interface. While the service-specific subsystem is common to all implementations, the network-specific subsystem varies depending on the network through which the digital signal is transported. For example, a DBS system uses a QPSK demodulator, a HFC system uses a 64 QAM or 16 vestigial sideband demodulator and conditional access/decryption system, and a FTTC system uses a baseband 16 CAP receiver to implement the network interface. Furthermore, realtime interactivity (an essential element of a video dialtone system) is provided through the network-specific subsystem.

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[22] M. Berniker, *AT&T Enters Digital Set-Top Market*, Broadcasting & Cable, Dec. 5, 1994 at 11.

[23] M. Berniker, *GI Shifts Back to Analog Set-Tops*, Broadcasting & Cable, Dec. 5, 1994 at 32.

The network-specific subsystem is important for video dialtone because it implements the network interface and therefore affects network cost and access. HFC bus architecture requires that more of the network functions be implemented in the set-top. For example, since all signals are broadcast on the HFC bus, every attached set-top receives all signals even though they may be destined for only one subscriber. Therefore, access to requested signals is granted through the network interface in the set-top. Generally, digital encryption will be used to implement this conditional access mechanism.

The HFC bus architecture imposes a further complication in the network termination in that RF subcarrier modulation is used to transport signals on the bus, therefore, the set-top contains the RF demodulator. Moreover, because efficient utilization of bandwidth is required to maximize the capacity of the bus, complex, multilevel modulation schemes such as 64 QAM and 16 VSB are used. Such signals cannot propagate error-free through the coax medium due to the reflections caused by the point to multipoint communication path from headend to subscriber and because of the poor condition of the typical home wiring. Therefore, in addition to the complex modulation scheme, HFC systems and thus the set-tops incorporate digital signal processing such as forward error correction to overcome the poor bit error performance. The result is considerable complexity in the set top network termination of the HFC system. This raises the cost of the set-top and complicates the specification of a standard interface.

In contrast, the FTTC system uses baseband signal transport of the native "ones and zeros" format of digital signals along with point-to-point connections between the headend and set-top to considerably simplify the network termination of the set-top. Furthermore, the access mechanism is implemented in the network rather than the set-top resulting in even further simplification relative to the HFC approach. This simplifies specification of a standard interface for the set-top manufacturer and, moreover, reduces the cost to the consumer.

BroadBand Technologies is committed to providing a standard interface between the set-top and the access network. Evidence of that commitment is the use of a standard format from the ATM Forum[24/] for the interface and the engagement of an outside semiconductor manufacturer to produce and make available to all the chips that implement the interface.[25/] The result will be lower-cost set-tops available from multiple vendors. Consumer choice is enhanced and competition is fostered.

24/ The asynchronous transfer mode (ATM) Forum is a private sector group of telecommunications service providers, equipment vendors, and end users seeking to advance the development of ATM technology. See *Telecommunications Reports*, Aug. 23, 1993, p. 34.

25/ See Appendix D, *BroadBand Technologies and AT&T Microelectronics Announce Cost, Technology Breakthrough for Interactive Video Networks*, news release, Dec. 6, 1994.

C. Digital Encoder and Video Server Technology is Commercially Available

Two important technologies are used to provide signal sources for the digital video dialtone facilities to transport to set-tops. For stored programming such as multimedia and movies on demand, a server is used to provide the signal source. For realtime video such as live events and broadcast programming, a digital encoder provides the signal source. The digital encoder is also used to digitize the programming for storage in the server. Both technologies are well along their development cycle. BroadBand Technologies has partnered with companies that manufacture or supply these devices to provide an end-to-end digital video capability.[26/]

Servers are being introduced by many suppliers. The function of the server is to provide the Level 2 gateway interface through which the subscriber selects the program of choice. The Level 2 function is also used to manage the playback of the digitally stored programs and provide interactive functions such as pause, rewind, etc. as appropriate. The principal technology being deployed is one that uses parallel microprocessors for control and magnetic media (disk drives) for storage. Trial systems have been in operation for well over one year and deployment systems are being planned and implemented at several sites around the world. The software that implements the user interface is being developed by many vendors and will be available with the hardware. Server cost is projected to be under $400

26/ *Interactive TV Leaders Cooperate to Deliver Video-on-Demand Services*, news release, April 20, 1994 (Appendix E).

per video stream. Assuming a peak usage of 25 percent, four homes can share each video stream on average resulting in a cost of less than $100 per home passed.

Digital video encoders are used to encode video for storage in servers. Several companies (notably Bell Atlantic and Digital Equipment Corporation ("Digital") have announced the creation of encoding studios for just that purpose. Encoders are also used to encode in real time for live video applications such as sporting events or broadcast programming. Such encoders are in use today in DBS applications. Because the digitized signal is broadcast over a large number of potential subscribers, the cost of realtime encoding facilities is highly shared. Today, typical encoders cost tens of thousands of dollars per channel. Encoders costs are projected to fall below $10,000 per channel. Given that an encoded channel would be broadcast to approximately 100,000 homes (the size of a typical headend), the cost per home passed is less than one dollar per channel. In time, when broadcast signals originate digitally, the cost per home passed will become negligible.

A recent example of the progress in developing digital video servers was Digital's announcement that it will publish an open interface standard (application programming interface) to ensure compatibility between its video servers and other manufacturers' set-tops.[27]

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[27] M. Berniker, *DEC Develops Server/Set-top Alliance*, Broadcasting & Cable, Dec. 5, 1994 at 34.

IV. The Commission Should Promote the Use of All-Digital Systems

BroadBand Technologies has endeavored in these comments to demonstrate that all-digital video dialtone systems are available and would be technically, operationally, and economically advantageous for the LECs to deploy. Moreover, there are strong public interest reasons for the Commission actively to encourage the use such systems.

First and foremost, all-digital video dialtone platforms comply fully with the Commission's core requirements for video dialtone systems: they provide sufficient capacity to serve multiple programmers on a nondiscriminatory basis and are expandable to meet additional demand for capacity. Most of the difficult regulatory problems the Commission must address in the various video dialtone proceedings arise from the technological limitations of analog and hybrid analog/digital video dialtone platforms. The channel-sharing plans and other complex proposed arrangements on which the Commission is seeking comment in this proceeding are attempts to overcome the capacity limitation of these platforms.[28]

Digital video platforms, in contrast, deliver hundreds of compressed digital channels of programming. The FLX system, for instance, is configured to deliver 384 digital "broadcast" channels of programming. All-digital platforms also can be expanded to meet

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[28] *Notice*, para. 271.

additional demand from programmers for capacity. The FLX system supports switched video services; thus, the system effectively is infinitely expandable.

While the Commission properly wishes to remain technology-neutral with respect to video dialtone deployment, it clarified in the *Reconsideration Order* that it is "not technology-neutral with respect to technologies that cannot meet" the core video dialtone requirements.[29]

Second, Commission action to promote the use of all-digital systems also will encourage LECs to accelerate deployment of integrated broadband networks. Before voting in favor of the video dialtone *Reconsideration Order*, Chairman Hundt said that one of his goals was to "make sure the telephone companies will have the incentives to build bigger and better pipes to simultaneously deliver voice dialtone and video dialtone."[30] In contrast to the FLX system and other digital video platforms, some of the alternative proposed video dialtone systems are "overlay" networks used to deliver video services only. The existing narrowband copper twisted pair network would continue to be used for telephony services. This is not the information superhighway of the future. Nor, we submit, is it what the Commission envisioned when it allowed the telephone companies to enter the video programming distribution market.

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[29] *Reconsideration Order*, para. 34.

[30] Statement of Chairman Reed E. Hundt on CC Docket 87-266 at Federal Communications Commission Open Meeting, October 20, 1994.

Third, steps to promote the use of digital video platforms would send a strong signal about the Commission's expectations regarding video dialtone systems. The capacity and expandability requirements reflect the Commission's expectation that video dialtone systems will be robust platforms capable of delivering video programming and other content on a common carrier basis. In the *Reconsideration Order*, however, the Commission "clarified" the expandability requirement, stating that it applies "to the extent that expansion is technically feasible and economically reasonable."[31]

The Commission cited strong reasons for qualifying the expandability rerquirement, and it pledged to evaluate claims that expansion is not technically feasible or economically reasonable on a case-by-case basis and "in light of all relevant circumstances."[32] However, this qualification could create incentives for LECs to opt to deploy less robust platforms with limited capacity but lower initial installation costs. As explained above, such systems can be more costly to expand than digital video platforms. In the future, LECs that deploy such systems could, therefore, argue legitimately that expanding the platforms would be economically unreasonable. This would frustrate the goals of the Commission's video dialtone policy. The Commission can eliminate these perverse incentives by actively promoting the deployment of digital video platforms.

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[31] *Reconsideration Order*, para. 38.

[32] *Id.*

The Commission can choose among several alternative approaches to ensure that LECs deploy video dialtone platforms that fulfill its expectations:

Option 1: Require LECs to Use All-Digital Video Dialtone Systems.

The first option, raised by the Commission in the *Notice*, would be to "require LECs to employ all-digital video dialtone systems."[33] Should the Commission determine that the benefits of digital video platforms justify mandating their use, the imposition of such a requirement would be well within the Commission's statutory authority and would be fully consistent with past Commission actions in similar circumstances. As the Commission previously has noted, the Communications Act of 1934, as amended ("Communications Act")[34] grants the agency "general authority to ensure that carriers subject to our jurisdiction furnish communications service upon reasonable request, in a just, reasonable, and nondiscriminatory manner, and with adequate facilities."[35] Section 151 of the Act mandates that the Commission regulate interstate and foreign commerce so as to make available "rapid, efficient, Nation-wide. . .communication service with adequate facilities at reasonable charges."[36]

33/ *Notice*, para. 270.

34/ 47 U.S.C.

35/ 800 Database, Memorandum Opinion and Order on Reconsideration and Second Supplemental Notice of Proposed Rulemaking, *supra* note 9, at 5427, citing 47 U.S.C. § § 154(i); 201-205; and 214.

36/ 47 U.S.C. § 151.

The Commission has exercised this authority in the past by requiring carriers to provide facilities necessary to achieve the goals and requirements of the Communications Act For example, the Commission required local exchange carriers to provide equal access facilities to interexchange carriers, based on a finding that the public interest benefits justified such a requirement.[37] In ordering the LECs to deploy the facilities, the Commission specified requirements for the technologies to be used in providing equal access. LECs that wanted to offer less than full equal access by the September 1986 deadline were required to seek a waiver from the Commission.

Similarly, the FCC in 1991 adopted an access time standard for 800 data base traffic and ordered the Bell Operating Companies and GTE Corp. operating companies to deploy the Signalling System No. 7 (SS7) facilities needed to meet the standard within eighteen months.[38] Specifically, the Commission ordered these LECs to install signal transfer points and implement SS7 interconnection sufficient to meet the standard for post-dial delay in the provision of 800 service.

The same considerations that prompted the Commission to mandate LEC deployment of these technologies are before the agency in this proceeding. The Commission determined

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[37] Equal Access, *supra* note 8; Illinois Citizens Utility Board Petition for Rulemaking, 2 FCC Rcd 1726 (1987). See also Public Coast Radiotelegraph Stations, 67 FCC 2d 790-821-22 (1978) (Commission recognizes its authority under § 214(d) of the Act to require upgrading of facilities as necessary to serve the public interest, convenience, and necessity).

[38] *800 Database*, Memorandum Opinion and Order on Reconsideration and Second Supplemental Notice of Proposed Rulemaking, *supra* note 9.

that equal access facilities and deployment of SS7, a digital technology, were necessary to ensure the emergence of competition in the interexchange services and 800 services markets, respectively. Because digital video platforms are expandable and provide sufficient capacity to serve multiple video programmers, they will further the Commission's goal of "facilitating competition in the provision of video services."[39]

In mandating the deployment of equal access facilities, the Commission specified minimum capabilities of the equipment to be deployed. Likewise, the Commission ordered the installation of SS7 facilities in order to meet minimum standards for post-dial delay in the provision of 800 service. Under the Commission's video dialtone orders, no LECs are compelled to offer video dialtone service. But if they do, the Commission has the authority to require that the technologies the LECs deploy meet the capacity and expandability requirements set out in the video dialtone orders.

In its order requiring LEC deployment of SS7, the Commission noted that "SS7 is a new network infrastructure that will not only support a number of new interstate and intrastate services, but also increase the efficiency with which LECs provide existing services."[40] The same is true of digital network platforms capable of delivering voice, video, and new broadband interactive services on an integrated basis. Commission actions that speed the deployment of such systems will further the other explicit goals of the video

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[39] *Notice*, para. 3.

[40] *800 Database*, Memorandum Opinion and Order on Reconsideration and Second Supplemental Notice of Proposed Rulemaking, *supra* note 9, at 5428.

dialtone policy, "promoting efficient investment in the national telecommunications infrastructure and fostering the availability to the American public of new and diverse sources of video programming."[41]

It should be stressed that a Commission requirement that LECs use all-digital video dialtone systems would still allow LECs wide latitude in choosing particular network architectures, service configurations, and vendors. The Commission would not, therefore, be dictating any particular implementation of digital technology. As discussed in section III A, above, there are substantial differences in architectures and capabilities among digital video platforms. Given the capacity and expandability requirements of the Commission's video dialtone rules, a requirement that video platforms be digital might properly be viewed as minimum service standard.

Option 2: Require LECs to Convert to All-Digital Systems by a Specific Date or When Certain Market Conditions Have Been Met

In the *Notice*, the Commission suggests that the short term economic and technical viability of digital video dialtone technologies is "unclear."[42] In these comments, we have endeavored to dispel these doubts. BroadBand Technologies recognizes, however, that in the short- and medium-terms, most televisions will be unable to receive digital programming absent a digital set-top, and most programming will continue to be produced in analog

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[41] *Notice*, para. 3.

[42] *Notice*, para. 268.

format. Eventually, digital CPE and programming also will be widely available at reasonable prices. The stated expectation of several LECs is that all video programming eventually will be carried in digital form on their video dialtone platforms.[43]

Given these facts, another option would be for the Commission to require that video dialtone platforms be all-digital by a date certain or upon the achievement of certain specified milestones in the diffusion of digital televisions, set-tops, and programming. The adoption of a digital standard with a deferred effective date would send clear signals to the LECs about the Commission's intentions and would create real incentives for LECs to deploy digital technologies. Such an approach would be consistent with past Commission actions. In the equal access and 800 database proceedings, the Commission required that facilities be deployed by a date certain. As in those cases, there is a sound basis for the Commission to find that the public interest benefits -- specifically, the availability of a robust common carrier video dialtone platform -- justifies the requirement that video dialtone platforms be all-digital following an appropriate transition period.

As described earlier, the next generation of the FLX platform includes the capability to deliver analog video signals. The analog transport capability was added in recognition of the current prevalence of analog CPE. The digital portion of the system remains fully expandable. None of the FLX system's bandwidth is used to carry analog signals; the analog transport capability is in addition to the "broadcast" and switched digital capacity of the

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[43] See e.g., U S WEST Investors Report.

system. Deployment of such a system would be fully consistent with a Commission rule that allows analog capacity on video dialtone systems on an interim basis, while requiring the eventual conversion of the system to full digital delivery.

In passband HFC systems, in contrast, the system's bandwidth must be shared between the analog and digital channels. If analog capacity is increased, the digital capacity is reduced, and vice versa. In HFC systems, the network operator must rob Peter to Pay Paul.

Option 3: The Commission Can Indicate Its Preference by Approving Applications to Build Digital Video systems on an Expedited Basis.

Another way the Commission can create incentives for LECs to deploy digital video systems is to expedite approval of Communications Act Section 214 applications to build such systems. Expedited approval of these applications is appropriate, since digital platforms comply with the letter and spirit of the Commission's capacity and expandability requirements for video dialtone systems. There is no need for elaborate channel sharing arrangements on digital systems; nor do such systems raise concerns about the nondiscriminatory treatment of competing video programmers. Such issues have arisen in the context of applications to deploy hybrid fiber/coax video dialtone platforms, and have required lengthy examination by the Commission.

Without prejudging the outcome of its consideration of these issues, the Commission can send a strong signal regarding its expectations by approving video dialtone applications that do not raise these concerns. The Commission already has approved one proposed commercial digital video dialtone platform, Bell Atlantic's proposed system in Dover Township. The Commission found that the FLX system being deployed in Dover Township "will offer capacity sufficient to satisfy the requirements of the [video dialtone] order."[44] According to the Commission, the system also "should result in investment in advanced communications infrastructure, which can contribute to economic growth and the nation's leadership in technology."[45]

Currently pending before the Commission are a second Bell Atlantic application for an all-digital system in Florham Park, N.J., and seven applications filed by U S WEST to build switched digital platforms with an additional analog transport capability.[46] These applications fulfill the Commission's expectations for video dialtone, and BroadBand Technologies respectfully urges the Commission to approve these applications promptly.

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[44] Dover Township, *supra* note 2, at 3680.

[45] *Id.* at 3681.

[46] U S WEST Communications, Inc., W-P-C-6919; W-P-C-6921; W-P-C-6922; W-P-C-6944; W-P-C-6945; W-P-C-7024 - 7027. As amended, these applications propose to deploy digital fiber-to-the-curb systems to deliver telephone, video, and interactive services on an integrated basis. U S WEST also proposes to address the transitional need to deliver analog video signals by integrating coaxial facilities into the platform for this purpose.

V. Conclusion

BroadBand Technologies respectfully requests that the Commission act on the *Notice* consistent with these comments.

Respectfully Submitted,

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December 16, 1994

CERTIFICATE OF FILING AND SERVICE

I, Kay Hawkins, hereby certify that an original and five copies of the foregoing Comments of BroadBand Technologies in file number CC Docket No. 87-266 were deposited for filing with the Office of the Secretary, Federal Communications Commission, Washington, D.C. 20554, this 16th day of December, 1994.

I further certify that a true copy of the Comments of BroadBand Technologies in CC Docket No. 87-266 was served by first-class U.S. mail, postage pre-paid, on each of the parties listed below this 16th day of December, 1994.

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ANALOG or DIGITAL:

ROBERT L. FIKE

The debate continues

An old debate is raging again—with a new twist. Given that TV signals and receivers are analog and given their eventual migration to digital, is it better to install analog or digital transport facilities?

The analog vs. digital debate has been going on for more than a quarter of a century. As each new telecommunications technology emerges, first in analog format and eventually migrating to digital, it is accompanied by a "new" debate about the merits and economics of the evolution to digital. The last debate centered around the use of digital switching in an environment dominated by analog signals and station sets.

A general discussion of technology evolution, with the migration from analog to digital switching as a specific example, indicates that the transition to digital may well be inevitable, the only question being one of timing. The migration of video from analog to digital is likely to follow the same course.

With that in mind, hybrid fiber/coax systems, which are inherently analog radio frequency (RF) systems, carry a potential obsolescence burden when compared with switched digital video systems. Deployment decisions must look beyond today's needs to make the best long-term decision for both cost and capabilities.

The Evolution

The evolution of a communications technology follows a reasonably common pattern of emergence, acceptance, maturity, decline and obsolescence. The shape of these curves traditionally was viewed as statistical normal distribution curves. Another view indicates that the decline phase of a given generation of technology may follow a more rapid "waterfall" pattern.

If one looks at the evolution of switching technology over time, a series of overlapping curves can be generated to represent the penetration of each generation of switching system technology at any given time (Figure 1). An important point to notice about this chart is the shortening of the cycles. Each new technology arrives sooner and matures more rapidly than the last one.

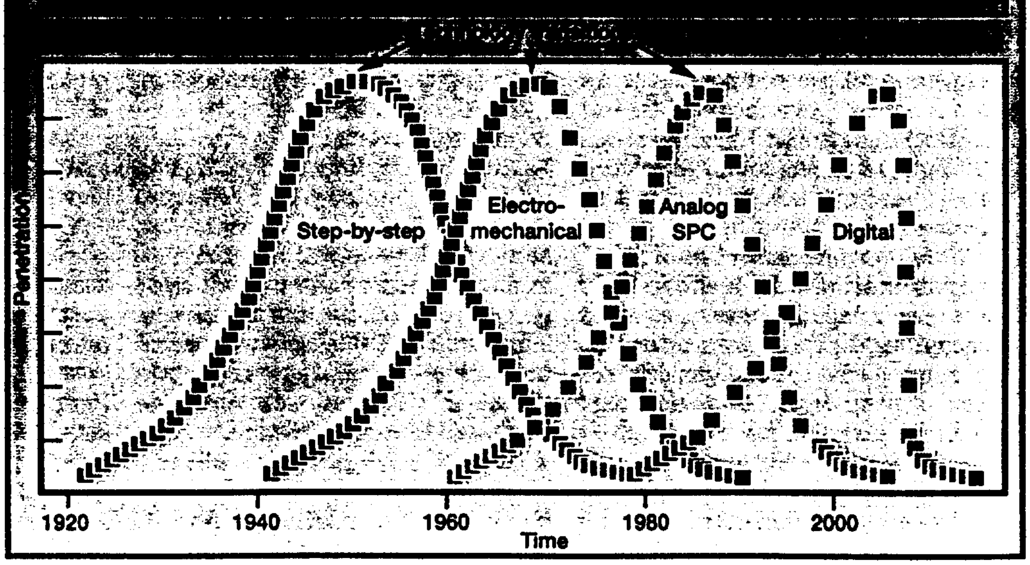
There are some fundamental cost drivers in these evolution patterns that are influenced by the conversion of processing electronics into silicon chips. Given the steep learning curve of digital processing electronics, the production cost of the processing power has reached the point that it is simply less costly to process information in a digital format than in an analog form.

Predictions as late as 1979 called for reductions in memory costs to as low as $2000 per megabyte by the mid-1980s. The price today is about $1 per megabyte. Analog technologies are not on as steep a learning curve, resulting in a gap between analog and digital electronics. This cost and processing capacity difference is growing and the gap continues to widen.

An interesting side issue is whether or not digital electronics in any application will displace analog electronics, given the low cost of digital electronics and the low cost of analog-to-digital conversion.

The major arguments supporting the continuation of the analog status quo during the early stages

FIGURE 1 TECHNOLOGICAL OBSOLESCENCE OF SWITCHING SYSTEMS



of the development of digital switching were:

- the existing base of customer premises equipment was virtually all analog;
- the cost of manufacturing analog was less;
- the feature set of analog was more robust;
- the reliability of analog systems was better; and
- the operational costs of analog were lower.

At the time the issue was being debated, each of the points raised above was completely true. In combination, those arguments would seem to pose an almost insurmountable barrier for a new technology to overcome. However, they reflected only a snapshot in time comparing a mature technology with a new one.

The arguments didn't reflect product evolution or technology learning curves; nor did they reflect changes in the external environment. Transmission was rapidly migrating to digital via T-1 carrier and digital loop carrier systems. And computer networking was just beginning to emerge as a market need.

By the time digital switching emerged from the laboratories, digital transmission, in the form of T-1 carrier, was already well on its way to becoming the dominant transmission medium in the interoffice world. A similar revolution was under way on the loop side of the business with DLCs. This movement toward digital transmission posed a serious problem for analog switches such as the 1AESS because of the digital-to-analog conversion required to connect the digital transport to the analog switch.

This transmission evolution meant that as far as the switch was concerned, the interfaces were becoming digital, in spite of the fact that CPE remained analog. As a result, the digital-to-analog conversion costs for the switch interface applied to both analog and digital switches.

Product evolution addressed the feature robustness issue. The inability of analog switches to handle all digital services posed a problem for the feature robustness argument, even if the demand for all digital services was less than clear. Over time, digital switches became more feature-rich than their analog counterparts, especially as more digital and complex business services were required.

Analog systems were not robust enough to support capabilities such as the Advanced Intelligent Network, TR-303 and the integrated services digital network. The waterfall replacement effect will cause newer digital technology to rapidly replace analog technology.

Over time, digital sets will replace analog ones and the last vestige of the analog network will disappear.

Operational cost differences and reliability differences were attributable to the lack of technological maturity of the digital systems and their novelty in the operations environment. In fact, the reliability of digital systems now exceeds that of their analog counterparts and their operational costs are now lower.

Given the steep learning curve of digital technology, it was simply a matter of time before the cost to manufacture digital switches became less than that for analog systems. Although the embedded base of CPE remains predominately analog and will likely remain so for the foreseeable future, the economics still favor digital switches.

The declining cost of digital processing technology has reduced the cost to perform the digital-to-analog conversion to a relatively minor portion of the overall system costs. All that could be done to address the CPE issue was to minimize the cost of supporting both classes of CPE and wait for market needs to cause a change.

Over time, digital sets will replace analog ones and the last vestige of the analog network will disappear. The net result of this technological maturation is that today's digital systems have more features, lower manufacturing and operational costs, higher reliability and will work with either analog or digital CPE at a total installed system cost that is less than half what it was for an analog system 10 years ago.

The initial Northern Telecom DMS-100 and AT&T 5ESS digital switches were deployed in the Bell System in 1982. There was a period during the early days of digital switching deployment when service providers looked at the cost of digital switches, their relative reliability and the initial lack of features when compared with the AT&T 1AESS, and sometimes made the judgment that it was better to install a mature product than risk the relative unknown.

The last new 1AESS was installed in the Bell regional holding company network in 1985. Because of long equipment depreciation schedules mandated by rate base regulation, it wasn't until the early 1990s that it began to be possible to replace the newest analog technologies with digital systems. It will take until at least 1998 before the most aggressive of the RHCs convert all of their switching systems to digital.

The Video Debate

As has been the case with the evolution of virtually every communications technology, the analog vs. digital debate continues with video delivery systems. The arguments being put forth vary depending on the source, but the structure of the debate is the same. Some of the pros and cons for each side are shown in Table 1.

There are advantages associated with using analog hybrid fiber/coax systems vs. all-digital transport technology. The three fundamental advantages of an analog system are the previously mentioned embedded base of both TV sets and programming content and the fact that digital systems require large bandwidth to deliver signals.

The latter point is not relevant,

since processing (compression) after the video signal has been digitized reduces the bandwidth required for transmission, so digital transport of signals actually increases the capacity of the system.

The embedded base of TV sets is analog and will be for a long time. There were about 25 million color TV sets sold in the U.S. in 1993 with between 180 million and 200 million sets thought to be in operation. Allowing for some growth in the number of in-use sets leads one to believe that 10 years is a reasonable period in which to change out the embedded technology if there were a driver to do so.

TABLE 1 ANALOG VS. DIGITAL VIDEO TRANSPORT			
Analog		Digital	
Pro	Con	Pro	Con
Analog CPE base	Interactive video capacity limitations	Interactive video capacity capabilities	Analog CPE base
Current analog programming content base	Inflexibility to service mix changes	System flexibility to accommodate changes in service mix	Current analog programming content base
Maturity of analog technology	System capacity upgrade and reconfiguration costs	Processing (compression, server and other digital technology) cost/capacity trends	Immaturity of digital video technology
Initial broadcast system cost	Complex and costly interdiction capabilities and RF engineering	Conversion of current analog programming content base to digital	Initial system cost
Bandwidth available for multiple services such as telephony	Security concerns for telephony applications in a broadcast system	Picture quality and consistency	Broadcast capacity requirements of digital systems without compression
Ability to incrementally add services	Digital signal transport complexity	System reliability	Real-time broadcast costs
[illegible]		Simplicity of upgrades	

Such drivers are beginning to emerge in the form of high-definition TV, multimedia and digital broadcast satellite systems, all of which use digital video signals. At least one TV set supplier, Phillips, has announced its intention to build a set that accepts digital input. Even if the sets were to remain analog, other forces will drive the transition to digital transmission and switching. For example, on the content side, efforts are currently under way by a variety of companies to develop digital libraries of programming content.

Video servers that are being developed are all based on digitally encoded versions of the content. Only live programming is likely to remain analog, and even that will be converted to digital by service providers such as DirecTV that are supplying digital video via satellite.

Furthermore, development of HDTV for broadcast markets is under way. Although the content isn't digital today, given the pace of change it seems entirely reasonable to expect high penetration of digital TV within 10 years. In addition, while the vast majority of telephony traffic continues to originate in analog format and will likely continue that way for some time, that is not the case for the new interactive video services that will originate in digital format.

Currently, digital systems must convert the analog content into digital format to transmit it and then convert it back to analog at the destination. These conversion costs are said to make an all-digital system prohibitively expensive, but that is not necessarily the case. An approach similar to that used for telephony networks, in which the complex electronics shared by many subscribers are located in the central office and simpler—which translates to cheaper—electronics shared by fewer subscribers are used in the outside plant, could be used in a digital video system.

"On-the-fly" digital encoders are available today at a cost of about $50,000 per channel. If that conversion were done at a central location, such as a satellite downlink or headend, and distribution beyond that were to be in digital format across a subscriber base in the tens or hundreds of thousands, the conversion cost would become insignificant.

At the destination end, the digital-to-analog conversion costs at a set-top level are less than $100 per subscriber. An important point to note is that these costs apply only to the broadcast channels. Virtually all of the interactive channels—such as delayed broadcast, true video-on-demand—will be stored in digital format and will be delivered as digital signals.

In those cases, analog systems will have to use some form of modulation and encoding system, such as 16 vestigial sideband (VSB) and 64 quadrature amplitude modulation (QAM), to convert the information into analog RF format and slot it into appropriate 6-MHz channels for transmission to the subscriber. The information would be demodulated and decoded at the destination.

These channels are dedicated to individual customers, so a typical modulator that supports six channels and costs about $2000 can only have its costs spread across those six customers. Such a cost could be prohibitively expensive for dedicated bandwidth services over analog hybrid fiber/coax systems. The balance between the number of broadcast channels and the number of interactive channels becomes a critical cost parameter.

When digital technology is used to increase the capacity of analog systems, the capacity of the system increases, but other disadvantages occur. The combination of digital and analog transport incurs all of the same encoding and decoding penalties that are attributed to digital transport systems, plus some significant additional ones. Because of the nature of the analog signal and the use of higher order modulation schemes such as 16 VSB and 64 QAM that are required to put the digital channels into the analog RF spectrum efficiently, higher cost lasers and amplifiers or line extenders are required to meet the linearity required for the lasers and the noise and interference concerns for the amplifiers.

In addition, higher bandwidth analog systems require closer spacing of amplifiers. As a result, a change from a 750-MHz system to a 1-GHz system requires a complete network redesign rather than simply changing equipment at each end of the network.

Digital transmission does not suffer from the same noise amplification problems that analog systems do. Digital equals clarity and consistency of picture quality plus capacity—and it adds the benefit of ease of switching video. Secondary benefits include integration with other digital technologies such as signal processing and information storage. Being able to apply digital processing means one can easily access applications that require concurrency such as a TV show with selectable rather than multiple language tracks.

Computing technologies, which are showing up in most aspects of our lives, are increasingly prominent in the areas of entertainment and education. What do a set-top box, a PC and a TV have in common? They've all got "Intel inside." The only differences are in the packaging and the applications software that comes with the box.

Expectations for the Future

Given the past experiences with transitions from analog to digital technology, one can predict what will happen in the case of hybrid fiber/coax and FTTC systems. In the next five years, digital libraries of programming content are likely to be established on national, regional and local levels. Real-time digital broadcast, with or without "on-the-fly" encoding, will be available much sooner than that.

In fact, the DirecTV service that is in the process of being rolled out now uses such technology. Interactive services that require set-top boxes, which incidentally provide marketing opportunities, will become common. Integrated digital PC/TVs will emerge on a commercial scale.

The cost and capacity trends associated with digital technologies are providing an ever-more compelling rationale for the evolution to digital communications technologies.

As the expectations described above are realized, digital video transport will happen. The questions are only ones of timing and how much money will be spent on analog technology that will have to be replaced before the rising of the inevitable digital tide. ■

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